I. RESONANCE CAPTURE OF SLOW NEUTRONS

II. UPPER LIMIT OF THE NUMBER OF LOW ENERGY NEUTRONS FROM A Ra-α-Be SOURCE

BY

A. AARON YALOW

A. B., Syracuse University, 1939

M. S., University of Illinois, 1942

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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R. UNIV. BIBLIOTHEEK LEIDEN

ABSTRACT

PART I

RESONANCE CAPTURE OF SLOW NEUTRONS

According to a theory proposed by Bohr,[1] nuclear reactions are the result of formation of a compound nucleus followed by emission of a particle or quantum. For medium heavy nuclei the levels of the compound nucleus involved in slow neutron capture were believed to be characteristically sharp, with a half-width of a few tenths ev and an average spacing of 10-30 ev. This hypothesis, to be referred to as Hypothesis A,[2] is consistent with the value of a few millivolts found for the radiation widths of all the previously analyzed levels involved in natural radioactive decay and with the experimentally found widths of the well-investigated neutron resonance levels.

Goldhaber[3] has found that some of the previously unanalyzed levels in Ra C′ with excitation energies of 2-3 Mev have widths of several ev. The hypothesis (Hypothesis B) has been offered[3,4] that the compound nuclear levels are characteristically broad, with widths of 1-10 ev, and that the sharp groups found have an origin other than the compound nuclear levels.

A systematic search has been made for the broad levels to be expected on Hypothesis B. Using a Geiger counter and associated scaling and recording circuits, the intensity of radiation induced by slow neutron bombardment in various detectors has been determined, with and without various filters and absorbers. The following resonance energies in ev, relative to the In (54 m) resonance energy assumed as 1 ev, have been obtained by the boron absorption method; Mn (2.59 h) ≥ 50; As (26.8 h) 55; Br (18 m) 43; Pd (13 h) 17; Ag (22s-A) 2.0; Ag (22s-B) 11; Ag (2.3 m) 35; I (25 m) 39; W (24.1 h) 9; Re (18 h) 22;

Many of the elements show mutual absorption; Ir and Re in particular show especially large absorption cross-sections with several detectors with a large range of resonance energies. This absorption may be attributed to wide levels in Ir (19 h) and Re (18 h).

A determination of the isomeric ratio of Br (18 m) to Br (4.4 h) shows that before filtration, the ratio of the saturation intensities is 2.71 ± 0.11 while after self-filtration through a 0.477 gm/cm^2 Br detector it is 2.78 ± 0.10. This constancy can most easily be attributed to absorption into a single level in Br.

When a 1.0 gm/cm^2 Br filter is used with a Br detector, the transmission of B is higher than with no filter, presumably due to the effect of the filter in straightening the neutron beam. Similar effects are observed with I, where they had previously been known, and As. It is therefore probably unnecessary to assume—as has been done in the past[2]—a complex level structure in these elements in order to explain the rise in B transmission when self-filtration is used.

Similar experiments with a Mn detector show a reverse effect. This can be attributed to the existence of two neutron energy regions in which Mn absorbs, a prominent "1/v" region at low energies and a resonance group at higher energies. To a first approximation absorption in these regions is shown to be independent.

For the Ag (22 s), Au, Ir, Rh and In activities, it has been found possible to practically eliminate the effect of the first sharp level by use of filters with levels overlapping the sharp detector group. Although this method should not affect any other levels which might exist, no evidence was found of further sharp groups. This result is in disagreement with the expectation of Hypothesis A that removal of the first sharp group should reveal further sharp ones with an average spacing of 10-30 ev. The apparent energies of the residual groups which were established are Ag (22s—B) 11 ev, Au (2.7 d) 53 ev, Ir (19 h) 36 ev. A possibly existing residual level in Rh has an apparent resonance energy of 16 ev.

The existence of a resonance group for Re (18 h) has been confirmed by self absorption measurements. A hitherto unknown resonance group with an energy of about 2 ev has been established for Re (90 h).

The results herein found appear to be more consistent with Hypothesis B than with Hypothesis A. A re-examination of the current concepts of nuclear level width would seem to be necessary.

PART II

UPPER LIMIT OF THE NUMBER OF LOW ENERGY NEUTRONS FROM A Ra-α-Be SOURCE

A method has here been developed to ascertain the upper limit for the fraction of the neutrons from a given source which are below a given energy, E.

A boron-lined proportional counter made of brass is used to determine the relative number of thermal neutrons produced by transmission through, or reflection from, thin layers of paraffin from a Ra-α-Be and from a Ra-γ-Be source. The difference in counting rate produced by interposition of Cd between the paraffin and the counter, which is shielded by Cd from all other sources of thermal neutrons, is determined for both sources as a function of paraffin thickness.

When reduced to a common sensitivity and the same number of incident neutrons, the initial slope of the growth curves of the thermal neutrons is at least 10 times larger for Ra-γ-Be neutrons than for Ra-α-Be neutrons. It is therefore concluded that not more than 10% of the neutrons from the latter source have an energy as low as the mean energy of the photo-neutrons from the Ra-γ-Be source.

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VITA

Abraham Aaron Yalow was born on September 18, 1919, in Syracuse, New York. He received his elementary education there and in New York City. He attended Syracuse University and received the A.B. degree, magna cum laude, from that institution in 1939 and the degree of Master of Science from the University of Illinois in 1942. During 1939-41 he was a University Scholar and a Graduate Assistant in Physics at Syracuse University. He held the latter position at the University of Illinois in 1941-42 and during part of the academic year of 1944-45. In 1942-43 and 1943-44 he was a Graduate Fellow in Physics at the same University. He is a member of the American Physical Society and is affiliated with Phi Beta Kappa, Sigma Xi, Sigma Pi Sigma and Pi Mu Epsilon.

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